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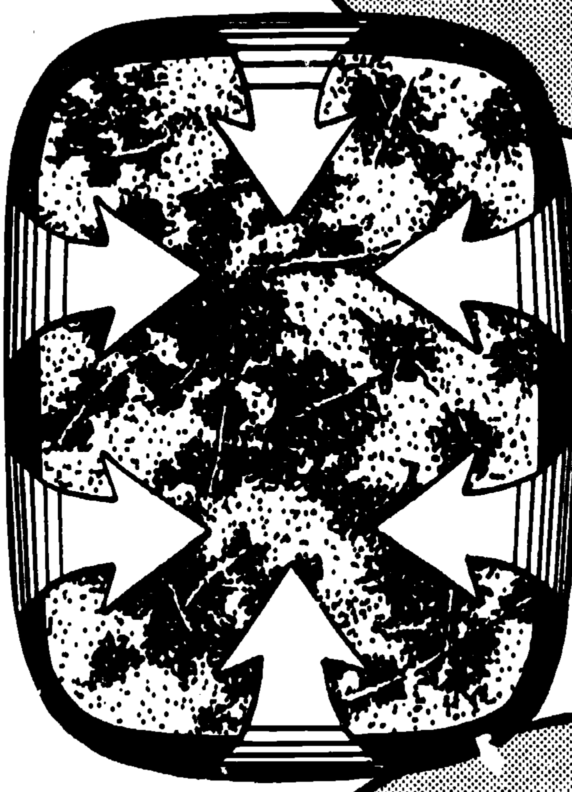
ABSTRACT

The textual material for a unit on facultative lagoons is presented in this student manual. Topic areas discussed include: (1) loading; (2) microbial theory; (3) structure and design; (4) process control; (5) lagoon start-up; (6) data handling and analysis; (7) lagoon maintenance (considering visual observations, pond structure, safety, odor, recordkeeping, and preventative maintenance); and (8) lagoon troubleshooting (considering causes and solutions to such problems as high loading, decreasing trend in pH, effluent high in biological oxidation demand, insects, and odor problems). A list of unit objectives, a glossary of key terms, a short list of references, and student worksheet are included. (JN)

Biological Treatment Process Control

Facultative Lagoons



Linn-Benton Community College
Albany, Oregon 1984

BIOLOGICAL TREATMENT PROCESS CONTROL

FACULTATIVE LAGOONS

STUDENT MANUAL

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FACULTATIVE LAGOONS

STUDENT MANUAL

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FACULTATIVE LAGOONS

Objectives

Upon completion of this unit you should be able to:

1. Give the unit for expressing organic loading.
2. Calculate organic loading rate.
3. Identify the three vertical zones of a facultative lagoon.
4. Identify the two ways that oxygen is supplied to a facultative lagoon.
5. Describe the algae/bacteria symbiosis.
6. Identify and describe the types of lagoon inlets.
7. Describe and give the advantages of the two types of outlet structures.
8. Describe the proper construction of lagoon dikes.
9. Calculate seepage rate.
10. Describe the only control parameter for single cell lagoons.
11. Describe the primary, secondary, and tertiary stages.
12. Describe parallel and series flow patterns and explain the advantages of each.
13. Explain the effects of natural factors (temperature, rain, wind, and sunlight) on treatment.
14. State how acidic pH can be corrected.
15. Explain how pond color can be used to evaluate pond condition.
16. Explain how chemical factors (nutrients, oxygen, pH) affect treatment.
17. List the tests that should be performed on the influent, the effluent, and the pond itself and explain what each test is used for in system operation.
18. List the visual observations an operator should routinely make.
19. Give one or two possible solutions for the following operational problems:
    - High loading
    - Decreasing trend in pH

Objectives Cont.

- High effluent suspended solids
- High effluent BOD
- Low D.O.
- Excess algae growth
- Insects
- Odor
- Dike vegetation
- Burrowing animals
- Water weeds

FACULTATIVE LAGOONS

Glossary

Aerobic Zone - The upper 80% of the lagoon when aerobic conditions exist.

Algae/Bacteria Symbiosis - The relationship between algae and bacteria where algae provide bacteria with oxygen by photosynthesis and the bacteria provide the algae with carbon dioxide as a by-product of respiration.

Anaerobic Zone - The lower depths of the lagoon where anaerobic conditions exist.

Cell - Each basin or pond.

Facultative Zone - The area between the aerobic and anaerobic zones which supports aerobic or anaerobic growth depending on whether or not oxygen is present.

Freeboard - The vertical distance from the water surface to the top of the dike.

Seepage - The loss of water from a lagoon by seeping through the bottom or the dikes.

Spring Turnover - The event that occurs when colder surface water with a heavier density settles to the bottom and displaces the warmer and less dense water upward. This often occurs in the spring as the ice cover melts and can result in odor problems.

FACULTATIVE LAGOONS

The theory behind facultative lagoon treatment lies with an understanding of some basic biological concepts. As with any biological treatment system there must be an interaction of microorganisms and food. This food is the wastes entering the system and can be divided into three types. These are soluble wastes, insoluble wastes, and floatables.

LOADING

Soluble wastes are the food source for the aerobic population and are an important factor in the metabolism of these organisms and their ability to stabilize the waste. Usually solubles present little problem unless they are present in excess, as will be discussed later. Insolubles and floatables, on the other hand, can pose significant problems. Insoluble organics settle to the bottom and are used anaerobically. This is normal and acceptable. However, insoluble inert material such as grit and sand often build up on the bottom and create short circuiting problems and shorter detention times in the lagoon. A large percent of these inerts will settle out near the influent structure and may cause plugged or partially plugged influent line. Floatables composed of plastics, grease, or sludge mats can create offensive odors and be an eye-sore. If present in excess these offensive solids need to be manually removed and disposed of properly.

The incoming organic wastes are metabolized by the bacteria. The strength of this waste is measured as Biochemical Oxygen Demand (BOD). The BOD test is used to calculate the lagoon loading rate and is a useful tool for process control. Loading to facultative lagoons is expressed as lbs BOD/acre/day. Normal design range is 15 - 30 lbs BOD/acre/day. The following formulas are used to calculate the loading rate.

1. Organic Loading, lbs BOD/day = Inf. BOD, mg/l X Inf. Flow, MGD X 8.34

2. Surface Area, Acres = $\dfrac{\text{Length (ft)} \times \text{Width (ft)}}{43560\ \text{ft}^2/\text{acre}}$

3. Organic Loading Rate (lbs/acre/day) = $\dfrac{\text{Organic Loading (lbs BOD/day)}}{\text{Surface Area (acres)}}$

Example: For a lagoon with the following characteristics:

Length	=	600 ft
Width	=	400 ft
Influent BOD	=	120 mg/l
Flow	=	150,000 gallons/day (0.15 MGD)

Organic Load (lbs BOD/day) - use formula #1

lbs BOD/day = 120 mg/l X 0.15 MGD X 8.34

lbs BOD/day = 150 lbs BOD/day

Surface Area (acres) - use formula #2

$$\text{acres} = \frac{600\ \text{ft} \times 400\ \text{ft}}{43{,}560\ \text{ft}^2/\text{acre}}$$

$$\text{acres} = \frac{240{,}000\ \text{ft}^2}{43{,}560\ \text{ft}^2/\text{acre}}$$

acres = 5.51 acre

Organic Loading Rate (lbs BOD/acre/day) - use formula #3

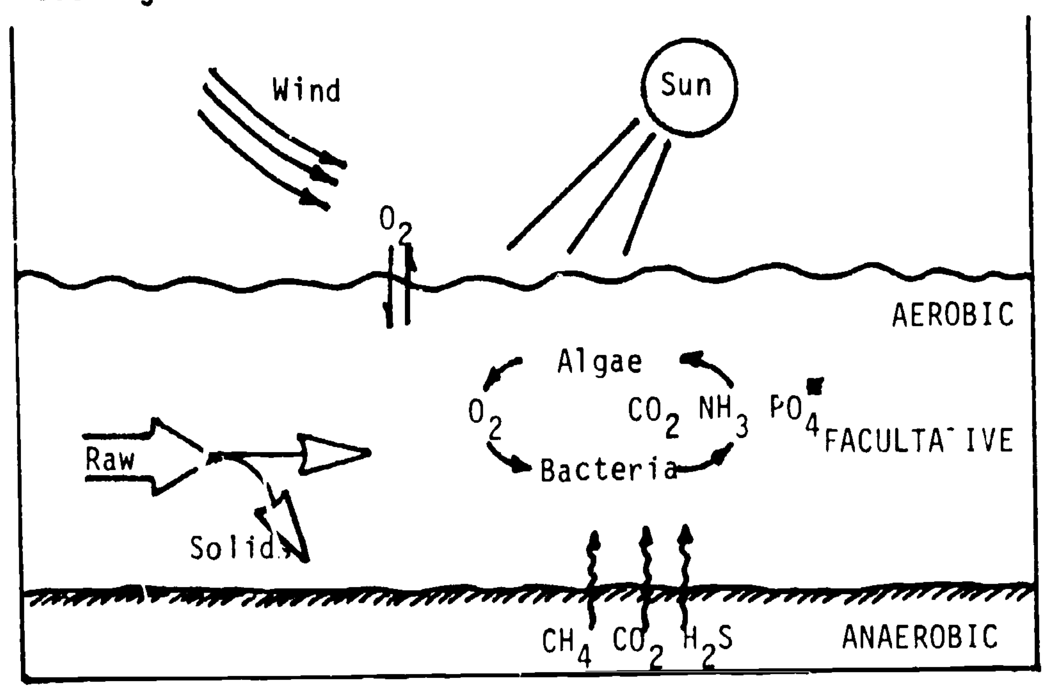
$$\text{lbs BOD/acre/day} = \frac{150\ \text{lbs BOD/day}}{5.51\ \text{acres}}$$

lbs BOD/acre/day = 27 lbs BOD/acre/day

If your lagoon is a regular geometrical shape the surface area can be easily calculated. However, if the lagoon is not rectangular or square the O and M manual or construction plans should indicate the surface area of the lagoon. The O and M manual should also include the designed loading rate and it is beneficial to compare actual loading rates as calculated above with the designed loading rate.

MICROBIAL THEORY

The microbial interactions (the process by which the wastes are stabilized) occur in two distinct zones. These are the anaerobic zone and the aerobic zone, and both are used in a facultative system to achieve waste stabilization. There is actually another zone: the facultative zone, which supports anaerobic or aerobic activities depending on whether or not dissolved oxygen is present. For our purposes the facultative zone will be included in the aerobic zone discussion since organisms in this zone usually metabolize aerobically and utilize available dissolved oxygen. See fig. 1 .



ZONES OF A FACULTATIVE LAGOON

Figure 1

The aerobic zone is found in approximately the upper 80% of the lagoon. It is here that the aerobic microorganisms use the soluble BOD and dissolved oxygen in their metabolic process. The oxygen is supplied from two sources: algae photosynthesis and surface aeration. Surface aeration is accomplished by the penetration of atmospheric oxygen into the liquid and is aided by winds and wave action, and from oxygen equilibrium between the water and air.

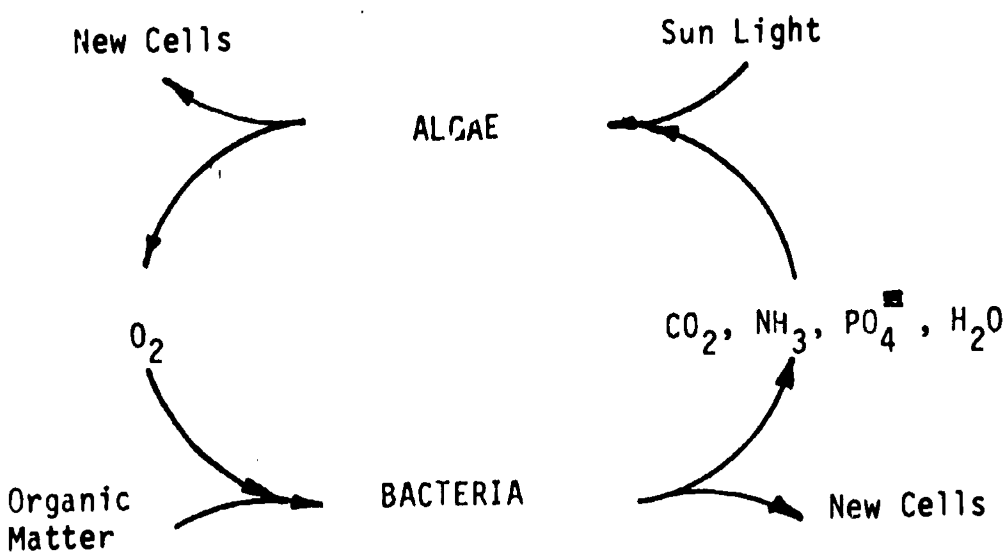
The microbial synthesis which takes place in this zone promotes new cell formation and leads to an increased biomass. As new cells are formed older ones die off. This results in the release of nutrients from the dead cells. These nutrients are composed of ammonia nitrogen, phosphate, carbon dioxide and water. These released nutrients are, in turn, reused by other bacteria and algae, or are discharged with the effluent.

The anaerobic zone, located in the lower depths of the lagoon, contain only anaerobic bacteria that use the settled wastes (BOD) and chemically bound oxygen for metabolism. Within this anaerobic zone a complex group of bacteria work together to further stabilize the wastes into stable compounds very much like an anaerobic digester.

Methane, hydrogen sulfate, carbon dioxide and ammonia are produced as metabolic end products. As these anaerobic microbes metabolize the wastes they also produce new cells and in turn some die off releasing nutrients as previously mentioned. Some of these nutrients are also utilized by algae and other bacteria in the aerobic zone. This aerobic/anaerobic inter-relationship helps to minimize overall sludge build-up in the lagoon system.

Because this aerobic/anaerobic relationship involves numerous biological interactions to fully decompose all the wastes, it is important that the system provides a favorable environment. There must be no toxic substances present, no wide pH fluctuations, and no limiting factors. Limiting factors in a facultative lagoon might include DO and/or nutrients. However, due to the algae/bacteria symbiosis and due to the natural make-up of domestic sewage these are usually not limiting. Nevertheless, both DO and nutrients should be monitored regularly for any indications of adverse or "upset" conditions.

The algae/bacteria symbiosis mentioned above is a process by which algae and bacteria give and take from each other. Algae, in the presence of sunlight, use the carbon dioxide, ammonia, and phosphate released from the bacteria (aerobic and anaerobic) to form new algae cells and, in the process, produce oxygen. The oxygen helps aerate the lagoon and is used by the aerobic bacteria. See fig. 2.



ALGAE - BACTERIA SYMBIOSIS

Figure 2

At nighttime the algae uses the dissolved oxygen in the lagoon and gives off carbon dioxide. This is the reason why at night facultative lagoons will have lower DO levels and lower pH's due to the buildup of CO_2.

In some cases, lagoons can actually become supersaturated with dissolved oxygen. This often happens in waters containing a large amount of carbonates and bicarbonates. The carbonates and bicarbonates supply the algae with extra carbon to utilize and therefore excess oxygen is produced. Generally, waters containing more than 9.2 mg/l oxygen is considered supersaturated.

STRUCTURE AND DESIGN

The structure of the lagoon should be designed to provide the best treatment possible. Design takes into account many factors, such as projected flows, type of wastes (i.e., all domestic, some high strength industrial, etc.) and upon the receiving stream condition. Each state has specific regulations governing construction and operation of lagoons, and it is advisable to contact your state environmental agency to familiarize yourself with the design criteria for your state. The following should be used only as general guidelines:

It is best to locate all lagoons far enough from residential sites so as not to present odor problems. This is also best for obvious safety reasons and to avoid any health hazards resulting from lagoon seepage into domestic groundwaters. It is ideal for facultative lagoons to be situated in open areas in order to get the benefit of surface aeration by the winds. This improves oxygen penetration and transfer and thereby aids in aeration of the waters.

Like any other type of treatment plant, most lagoons have some form of pre-treatment. These usually consist of bar screens, grinders, flow meters, grit removal, and sometimes, pre-aeration. A lagoon system may only have one of the above pre-treatment devices or may have a combination. This is largely dependent upon the types of wastes and individual needs.

Lagoon inlet structures are usually one of two types. One type feeds the lagoon at one corner, as illustrated in fig. 3. The flow continues into each successive pond or, if it is a single cell type, discharges at the opposite end.

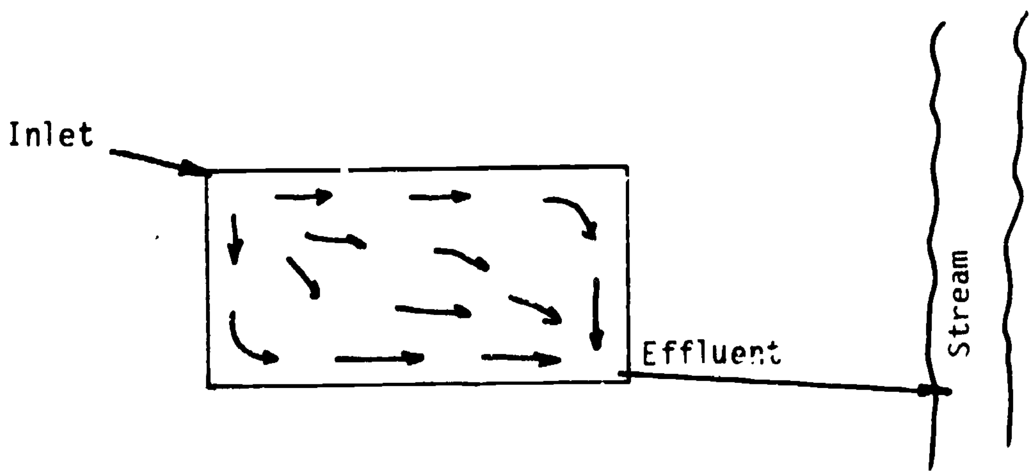


Figure 3

The other type of inlet structure, an American favorite, is constructing the pond circular with the influent feed in the center and the effluent at one edge. See fig. 4.

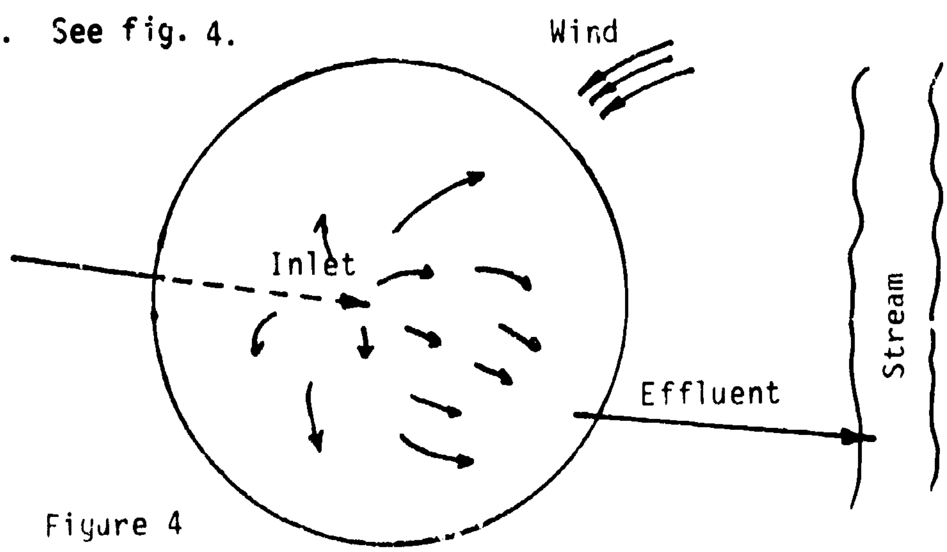


Figure 4

This is advantageous if prevailing winds change direction frequently, since the flow pattern will be constantly redirected. In facultative systems, especially singular cell systems, wind currents govern the direction of flow. It is easy to understand how short circuiting can occur and shortened or lengthened detention times. The center-feed type is also good for distribution of solids because it minimizes the solids built up around the inlet structure.

Some lagoons have multiple inlets which provide a step-feed opportunity. This enables the operator to have some control over detention times. Since longer detention times generally result in less algae at the effluent, control over detention time also enable the operator to control algae problems.

Outlet structures are always at one edge and are more beneficial if designed for subsurface withdrawals. This allows the operator the option of se cting the appropriate depth from which to withdraw effulent; a distinct advantage if algae is a problem. Subsurface outlet structures also permit adjustment of lagoon depth which is used for weed control and for adjusting detention times. If a lagoon has surface withdrawal, baffles and/or weirs are often used to help keep algae out of the effluent.

The effluent flow is usually monitored by either flumes, weirs, or metering devices. This measurement is useful for calculating the seepage rate which will be covered later. Effluent flow is also chlorinated. The chlorination process can occur in a contact basin, but more often, is injected into the effluent line prior to the contact pipe and outfall line. It is important to adjust the chlorine feed rate to get a good coliform kill without discharging excessive residual. Usually 1.0 mg/l of free Cl_2 residual is the maximum limit allowed in the effluent. Again this varies and is dependent upon the receiving stream. Check your individual discharge permit for Cl_2 residual limits.

The cell or cells of a facultative lagoon consists of 3 components. These are the dike, the lagoon bottom, and the cell dividing walls (for multicell lagoons only).

The dike should have a 3 foot freeboard, be impermeable, and be sloped with a 3:1 ratio (i.e., 3 ft horizontal to 1 ft vertical). It is also necessary to be able to drive on the dike and for this the dike should be at least 8 feet wide.

The lagoon floor should be constructed so as to limit any seepage. This criteria is state regulated. In Oregon the allowable seepage rate is no more than 1/4 inch per day. Controlling seepage can be accomplished by using impermeable material such as bentonite clay, or plastic liners. To calculate seepage use the following seepage formulas. The weather bureau can be a source of information for the evaporation and precipitation rates.

<u>Seepage</u> (inch/day) = INPUT - OUTPUT

= (Inf + Precip) - (Eff + Evap)

1. <u>Influent</u> (inch/day) = $\dfrac{\text{Total Flow For Year (gal/yr)}}{\text{Surface Area (ft}^2\text{) X 228}}$

2. <u>Effluent</u> (inch/day) = $\dfrac{\text{Total Flow For Year (gal/yr)}}{\text{Surface Area (ft}^2\text{) X 228}}$

3. Precipitation (inch/day) = $\frac{\text{Weather Bureau (inch/yr)}}{\text{365 days/yr}}$

4. Evaporation (inch/day) = $\frac{\text{Weather Bureau (inch/yr)}}{\text{365 days/yr}}$

EXAMPLE 1

a) Influent = 54,700,000 gal/yr

b) Effluent = 52,000,000 gal/yr

c) Precipitation = 12 inch/yr

d) Evaporation = 22 inch/yr

e) Surface area = 250,000 ft^2

1. Influent (inch/day) = $\frac{54{,}700{,}000}{250{,}000 \times 228}$

= 0.96 inch/day

2. Precipitation = $\frac{\text{12 inch/yr}}{365}$

= 0.03 inch/day

3. Effluent = $\frac{52{,}000{,}000}{250{,}000 \times 228}$

= 0.91 inch/day

4. Evaporation = $\frac{\text{22 inch/yr}}{365}$

= 0.06 inch/day

SEEPAGE = INPUT (inch/day) - OUTPUT (inch/day)

INPUT = Influent (inch/day) + precipitation (inch/day)

= 0.96 to .03

= 0.99 inch/day

OUTPUT = Effluent (inch/day) + Evaporation (inch/day)

= 0.91 to .06

= 0.97 inch/day

SEEPAGE = INPUT - OUTPUT

= 0.99 inch/day - 0.97 inch/day

= 0.02 inch/day

Single cell lagoons are usually less than one acre in size. Anything larger requires two or more cells to achieve adequate treatment. The projected flows and loading rates are the determining factors for lagoon size and design. Multicellular lagoons are divided in one of two ways. The most common type is to have the two ponds side by side with an earth dike between them. Other methods, such as cement walls and plastic liners, allow one lagoon to be divided into individual cells. These designs usually offer more flow control and offer a wider variety of operational alternatives.

PROCESS CONTROL

Once a good understanding of the biological concepts and basic design criteria has been reached the lagoon operator can use this knowledge to effectively practice process control. Although process control strategies are more limited for lagoons than for other types of treatment facilities, there are some definite control parameters which are useful in maintaining a normal health lagoon and producing high quality effluent.

Single cell lagoons have only one control parameter. This is water depth. Controlling water depth results in control over detention time.

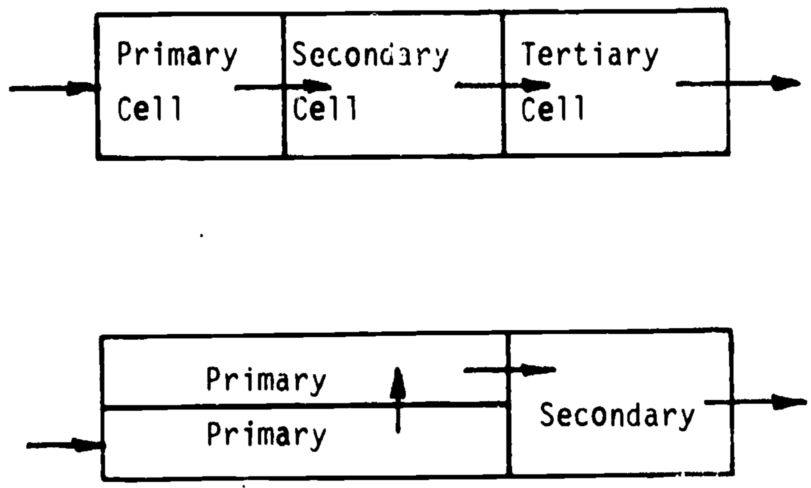
Multiple cell lagoons, on the other hand, offer more operational flexibility. Multiple cells can be used in stages. These are the primary stage, the secondary stage, and the less common tertiary stage.

The primary stage is that cell or cells which first receives the incoming wastes. It's here that the food (BOD) comes in contact with the microorganisms and stabilization begins. The primary stage is in some ways comparable to a primary clarifier in an activated sludge plant. However, unlike a primary clarifier the long detention times also allow the microbes to carry out the stabilization process. This includes microbial growth and reproduction, the same processes which occur in a mixed liquor basin. This "aging" process aids in the settling which takes place in the secondary stage.

The secondary stage is basically a settling stage. The microbial activity is decreased and the stabilized solid wastes settle out. This is comparable to a secondary clarifier in an activated sludge treatment plant.

The tertiary stage, sometimes seen in lagoon systems, is the last stage and is used primarily for algae removal. The loading to these ponds is usually very low (15 lbs BOD/acre/day). Tertiary ponds are sometimes utilized for nutrient removal prior to discharge in order to minimize stream pollution caused by excess nitrogen and/or phosphate.

Multiple cells also offer two different modes of operations. The series mode, shown in fig. 5, is a plug flow mode in which the wastewater enters one cell and continues into each successive cell in series.

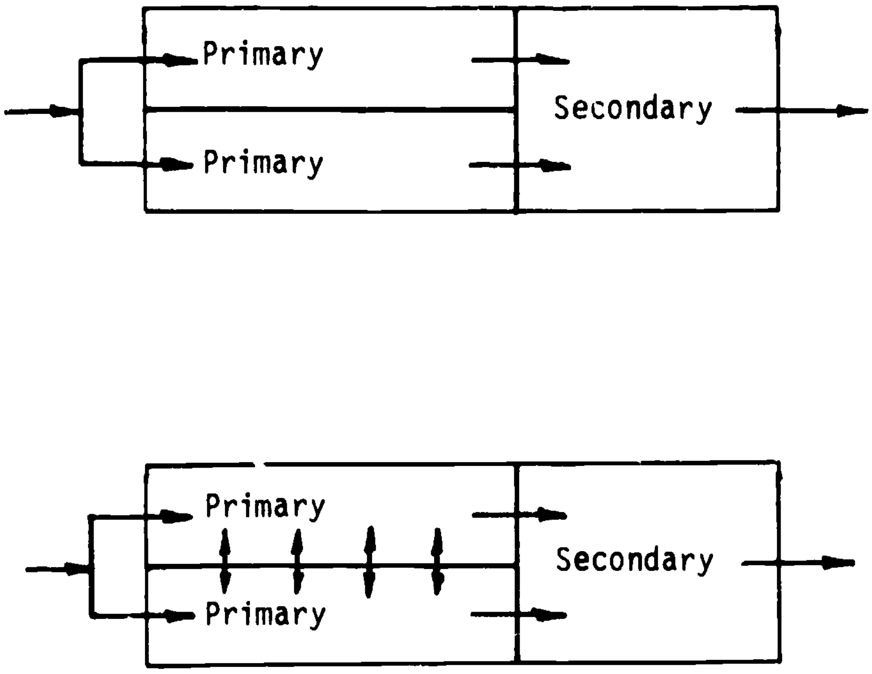


SERIES MODES

Figure 5

The series mode offers long detention times and good algae removal. The limited microbial activity following two primary cells in a series results in a lack of released nutrients. This limits algae growth. The series mode is designed for, anu is most effective under low loading conditions. Under higher loading conditions the primary cells become hydraulically and biologically overloaded which can result in only partial stabilization of the wastes. This, in turn, will adversely affect the secondary stage by overloading it with unstabilized wastes which inhibit settling.

The other mode of operation is the parallel mode shown in figure 4a. The flow in this mode is split into the two primary treatment cells and then proceeds to flow jointly into the secondary cell. The primary cells can be either completely separated or share a common wall in which there is a cross flow pattern keeping the two cells consistent with each other. This type of parallel flow is shown in figure 6 .



PARALLEL MODES

Figure 6

Parallel mode operation is used for higher loading conditions since it is capable of reducing the organic and hydraulic load in the primary stage. With longer detention times and better distribution of the solids, there is much better treatment. This mode is also advantageous in winter months when biological activity is greatly reduced.

There are three operational alternatives for the effluent flow. These are continuous discharge, controlled discharge, and no discharge.

The most common of these is the continuous flow. The flow is constantly entering and leaving the lagoon at approximately the same rate, and therefore needs to be continously chlorinated. Controlled discharge is when the effluent is contained for long periods of time. This "holding period" may be determined by the regulatory agencies and is primarily dependent upon receiving stream conditions. The normal discharge for these facilities is twice a year, usually after the first frost in spring and in the fall when algae is at the lowest concentrations. Some lagoons discharge into small creeks whose flows are seasonal and therefore require the effluent discharge to be seasonal also. Chlorination is required only while discharging.

The last type is called a "no discharge" pond. This lagoon facility is designed with no discharge structure and totally utilizes evaporation and percolation to dispose of wastewaters. These ponds are only feasible in areas of hot climate and have a large surface area and shallow depths. They can become too shallow and experience weed problems. One method to control weeds is to add fresh water as needed to discourage weed growths.

There are other flow control possibilities. One is a step feed program in which there is more than one inlet structure either into the primary cells or from the primary cells into the secondary cell(s). The advantage of step feeding is the even distribution of solids which minimizes solids buildup. Some lagoons are set up with recycling capabilities. Secondary pond water is recycled back to the primary cell(s) to aid in algae control and to supplement DO levels. Secondary ponds have higher DO concentrations produced by the algae and this water is recirculated back into low oxygen areas. Recirculation in conjunction with chlorination can be effective in controlling algae. Chlorination and recirculation result in the algae mass settling prior to discharge and better effluent quality is obtained.

Depth control can also be used by the operator in multiple cell systems. Pond depth is variable with a minimum depth of two feet and a maximum depth of five feet. A normal depth for facultative lagoons is approximately four feet. This allows adequate mixing between the lower and higher DO layers so that adequate DO is maintained in the aerobic zone.

In some circumstances cell isolation is required if a particular cell becomes upset and septic conditions occur. Toxic wastes can be isolated in this manner before lagoon performance is affected. Cell isolation is also used for maintaining and cleaning individual cells or for cell repair in cases of seepage.

Because lagoons are biological systems, they are subject to several factors which can affect treatment. There are three general categories which directly affect lagoon performance. These are natural factors, physical factors and chemical factors.

Natural factors include such phenomena as temperature, rain, wind, and sunlight.

Wind is important because it creates surface mixing which will affect DO concentrations. This aids in increasing aeration and permits surface DO to penetrate deeper into the ponds.

Temperature of the lagoon water is important since the micro-organisms are very sensitive to changes in temperature. Activity doubles with every $10^{o}C$ increase and decreases by 1/2 with every $10^{o}C$ drop in temperature. A sudden change in temperature can temporarily affect effluent quality. For example, a rapid decrease slows algae activity which cause the algae to settle better and results in clearer effluent.

Controlled discharge ponds usually discharge in spring and fall for this very reason. Conversely, a rapid increase in temperature increases biological activity. This results in an increased DO demand which the algae can't supply fast enough. Thus, DO concentrations temporarily decrease and effluent may become more turbid.

Prolonged periods of warm or cold temperatures also have an impact on lagoon treatment. Cold temperatures combined with shorter daylight hours slow microbial and algae metabolism and therefore a longer detention time is needed to achieve the same degree of treatment. This lower algae metabolism also results in an effluent lower in suspended solids. Ice covers, which are always a possibility, will temporarily create anaerobic conditions. When the ice cover melts "spring turnover" is experienced which will cause odor problems for a short period of time. Spring turnover is a result of stratification and temperature change. It occurs when colder surface waters with a heavier density settles to the bottom and "pushes" the warmer and less dense water upward. This mixing effect will temporarily cause turbidity and may deteriorate effluent quality.

Warm temperatures, on the other hand, increase biological activity and create a greater DO demand. The increased demand is usually satisfied by increased algae metabolism. This helps to minimize the DO depletion during the warmer months. Since the amount of sunlight influences the amount of algae growth, it is at this time that algae blooms can become a problem. Algae blooms, in turn, cause the effluent to be higher in suspended solids and BOD.

The warm weather in spring and summer also causes vegetation and water weeds to appear. It is very important to control this growth early in order to prevent future problems.

The major impact of temperature is its effect on DO concentrations. Warmer waters hold less oxygen than colder waters. As an example, water in the winter will hold approximately twice as much oxygen as it will in summer.

It is important for the operator to be aware of these temperature fluctuations and their related problems. Temperature monitoring can be a useful tool in determining the reasons behind certain lagoon conditions, and therefore is a very important process control parameter.

Sunlight and rain, two other natural phenomenon, are also of concern for lagoon operation. Heavy rainfall causes shorter detention times, dilutes the organic wastes, and can cause special problems for the controlled discharge lagoon. These lagoons may fill to maximum capacity during their holding period and special permission may be needed to discharge.

Sunlight is an essential ingredient for photosynthesis of the algae which, in turn, provide a large percentage of the DO. During months with little sunlight, it is sometimes beneficial to lower the depth of the lagoon to allow better sunlight penetration. The density of the algae mass and other water vegetation such as duckweed will also affect sunlight penetration and therefore should be dispersed or removed. Ice and snow covers can also decrease light penetration causing decrease algae activity and lower DO concentrations.

The physical factors which affect treatment include loading rates, water depths, short circuiting, and operational modes.

When surface loading rates go beyond design criteria overloading occurs which causes an increased microbial activity. This increased microbial activity, in turn, decreases DO concentrations and the hydraulic overloading decreases detention times. Both of these types of overloading create conditions which do not allow for complete stabilization of the organics. If stabilization is not completed prior to discharge, the lagoon effluent will be high in BOD and suspended solids concentrations. This will cause severe loading on the receiving stream and DO depletion can result.

As mentioned earlier, water depth should never be below 3 feet to prevent weeds from growing on the lagoon bottom and to help maintain adequate treatment zones. This minimum depth also keeps the settled sludge blanket covered and consequently prevents the bottom from drying and cracking. For controlled discharge ponds, the operator must determine when and how low to lower pond levels prior to the holding season. This decision is important to insure adequate holding space during that holding period.

Short circuiting occurring in lagoon operations can be caused by the following conditions: poor design of inlet and outlet structures, unlevel bottoms, cell shape and size, uncontrolled water weeds, and wind conditions. These factors will hinder desirable flow patterns and/or detention times and create a condition known as dead spots which reduces the area of effective treatment and could even contribute to some odor problems.

The last physical factor is operational mode changes. There are the three types of modes which were mentioned earlier. They are: series, parallel, and a recycling mode. Series consists of two or more operating cells and reduces algae in the last stage of treatment. This results in better effluent quality and is used in warm months when algae can be a problem or when loading conditions are low. Parallel mode consists of three or more cells and is used for high load conditions. It is also advantageous to use parallel mode in winter so as to distribute the loading over a wider area and thus increasing the detention time in the primary stage. Recirculation is another physical mode characteristic in which the higher DO concentrations of the effluent is reused in low DO areas to help supplement the oxygen content. The most common recirculation method is to recycle the effluent from the secondary cell to mix with the effluent from the primary cell. Recirculation can be used with either a parallel or series mode.

Chemical factors which influence lagoon operations include oxygen concentrations, nutrient levels, and pH. Oxygen is an essential chemical constituent for biological metabolism. This oxygen can either be free O_2 which is used by the aerobic microbes, or chemically bound O_2 which is used by the anaerobes. In the first stages of the stabilization, complex organic molecules are broken down into simpler organic compounds. These simpler compounds are then further oxidized by the bacteria. This process depletes the DO concentration in proportion to the amount of organic material present and is known as the oxygen demand of the wastes. This demand is determined by the Biochemical Oxygen Demand test, or BOD. Insufficient oxygen levels will cause a turbid effluent, undesirable odors, and can be the cause of uncontrolled filamentous growths. Filamentous growths can cause poor settling and deteriorates effluent quality. If the oxygen demand is greater than the available oxygen, then the aerobic activities cease and anaerobic conditions develop.

Nutrients, such as ammonia nitrogen (NH_3) and phosphate (PO_4), can also influence lagoon treatment. They are needed by the bacteria to stabilize the organics. A deficiency of one or another of these nutrients can be a limiting factor in biological activity. Fortunately, domestic waste usually contains enough of the required nutrients. Other micro nutrients which are required for metabolism are iron, sulphate, calcium, potassium, and magnesium.

pH is also a critical chemical factor affecting lagoon operation. Microorganisms function best under slightly basic conditions (between 7.0 and 9.0). End products from the bacte a lgae symbiosis, such as CO_2, will have a lowering effect on the pH. This lowering effect will cause a shift in microbial populations and types. For example, odor causing algae, such as the blue-green, need a pH of 6.5 or less. Green algae, which are the desirable algae form, need a pH of 8.0 - 8.4. An acidic pH condition can be corrected by letting the cell rest for a few days. This resting period equalibrates the end products from the microbial interactions. pH should be measured at the same point each day and should be measured on-site because pH can change quickly. pH changes occur naturally throughout the day and will vary depending on the time of the day. For example, pH will be at its lowest at sunrise and highest in late afternoon. This happens because photosynthesis stop but metabolism continues at night. This results in a release of extra carbon dioxide (CO_2) into the water and causes the pH to lower. An observant operator will notice the correlation between pond color and pond pH. A sparkling green color is indicative of basic pH levels, whereas a yellowish-green appearance is indicative of an acidic pH and unfavorable conditions. However, one must keep in mind that pond color may be due to outside factors such as stratification or wind churning up the silt from the bottom of the lagoon.

LAGOON START-UP

When starting up a new lagoon or bringing on a newly constructed cell or cells, it is best to start-up during spring and summer months due to warmer water conditions. This provides for rapid development of microbial populations. After the wastes have been introduced to the lagoon, algae blooms will usually appear in 7 to 14 days. A well balanced microbial population will usually appear within 60 days. The pond(s) should, by this time, have a definite green color which indicates a slightly alkaline condition and good algae growths. Fall and winter start-up procedures present some potential problems with freezing and slower microbial activities. Under these conditions it may take longer for the algae/microbial populations to reach a balance.

The general procedure for lagoon start-up is as follows:

1. Fill as rapidly as possible with fresh water to discourage weed growths and odor problems.
2. When starting a multi-cell lagoon, fill only primary cell(s) to about the 2 foot level.

3. Blend in the wastewater keeping the pH greater than 7.5 and checking DO levels daily.
4. When primary cell(s) reach 3 feet, begin filling the secondary or successive cell(s).
5. Feed fresh water into secondary cell(s) until a depth of 2 ft is reached.
6. Add water to the secondary cell(s) from the primary cell(s).
7. When drawing water out of primary cells, use only the top portion and do not ever let primary stage fall below the 3 foot level.
8. Equalize all water depths by retaining the effluent and recycling it back if needed to any pond or ponds that need equalizing. Repeat this process using only 6" water level increments until all ponds reach optimum operating depths.
9. When all ponds are filled equally, begin discharging effluent.
10. While filling successive ponds, it is also important to closely monitor DO and pH.

DATA HANDLING AND ANALYSIS

In order to effectively practice process control at any treatment facility, it is necessary to perform a number of testing procedures. An understanding of your plant's data will help you operate the system effectively. The facultative lagoon, as simple as it is in terms of design and operations, is no exception. There are sampling procedures and control tests that can be utilized by the operator to help gain an insight into the lagoon's efficient performance or lack of it.

We must first consider sampling which is the basis for all data handling. There are two types of sampling techniques. The first and most widely used for lagoon operations is the grab sample. This sample is "grabbed" during an average flow to represent average flow conditions. The second sample type is a composite sample usually taken with the use of an automatic sampler. This sample is taken periodically, either on a time or flow basis, to more accurately represent the total flow. A composite sample is a series of small samples composited into a large container. For lagoons it is best to use a composite sampler at the influent due to the variable flow conditions. If possible a composite sampler should also be used at the effluent.

For actual cell sampling it is more practical to use a grab sample due to the long detention times and the inaccessibility of the sample points. For effluent sampling, whether it is a grab or composite, it is advisable to take the sample after chlorination to obtain accurate coliform test results. Bear in mind, though, that during months high in algae growths, chlorination of the effluent will cause a marked increase in BOD. The chlorinated algae will die and settle which results in lower effluent suspended solids but the release of soluble substances will increase effluent BOD.

When gathering samples from the cell or cells, it is important to grab the samples at the same location(s) in order to accurately compare daily data. One example used for cell sampling is grabbing a sample from each corner and then compositing these into one sample. Some lagoon operators take their sample(s) in the middle of the cell(s), feeling that it is representative of the whole cell.

Samplers used to grab samples should allow collection of water below the surface. Samples should then be immediately put into a clean storage bottle with a snug cap to prevent any contamination. The samples should then be refrigerated as soon as possible. Samples stored at $4^{0}C$ may be preserved for twenty-four hours. The exception to this is the coliform sample which should not be stored any longer than six hours.

The next step after sampling is performing the different control tests. The type and frequency of these tests depends on each individual lagoon's permit. The following tests may not be a requirement of your NPDES permit but they have been found to be useful in maintaining good process control.

<u>Influent testing</u> is extremely important because it measures the amount and type of wastes entering the lagoon. From this information is derived a very important process control parameter: the <u>loading rate</u>. The loading rate, which is determined by influent flow and BOD, is necessary for any operational mode changes. Therefore, it is important that the influent flow be recorded daily. If a flow chart is used it needs to be changed regularly. Flow recording is also important for any indications of infiltration and/or seepage.

Equally important is the BOD test which measures the organic concentration of the waste. The frequency of the BOD test for operational control is determined by each individual lagoon. If waste characteristics change frequently, it is a good idea to run BOD's more often. If your effluent quality is deteriorating and overloading is suspected, BOD's should be run immediately and daily in order to follow the trends and determine if a mode change is required. The organic concentration of the wastes affects the biological activity in the lagoon which directly determines the degree of treatment obtained. Because of this it is important to know if you have a high strength or low strength influent. Although most lagoons don't have any control over their MLSS concentrations and therefore no control of the F/M ratio (food/microorganism), it is important for operators to understand that the incoming organics (BOD) will either adversely or inadversely affect treatment. The microorganisms will metabolize more rapidly in the presence of high BOD and will die off when the high BOD suddenly drops off. The bacteria growth phases of a lagoon may be constantly "peaking and ebbing" depending on influent conditions. Fortunately, most lagoons have a fairly consistent waste strength and BOD flucuation is not a problem.

Influent BOD is also required in determining the lagoon's removal efficiency of total BOD. The percentage of BOD which is removed from wastewater is proportional to the degree of stabilization obtained. For example, if a lagoon influent is 230 mg/l BOD and the effluent is 40 mg/l BOD the lagoon has a 83% removal of BOD.

$$\%\ \text{Removal} = \frac{\text{BOD in} - \text{BOD out}}{\text{BOD in}} \times 100$$

$$\%\ \text{Removal} = \frac{230 - 40}{230} \times 100 = 83\%$$

Another important test run on lagoon influent is suspended solids. This value, also expressed in mg/l, is used to measure the amount of solids entering the lagoon. By using the lbs formula:

$$\text{lbs} = \text{Vol (MGD)} \times \text{Conc (mg/l)} \times 8.34$$

the suspended solids concentration can be converted into pounds which can be used for sludge inventory. By calculating total pounds entering the lagoon over a period of time and then subtracting total pounds leaving the lagoon (i.e., effluent), you can get a fairly good idea of how much sludge has accumulated on the bottom in the anaerobic zone. Influent suspended solids is also necessary for calculating percent removal of suspended solids.

$$\%\ \text{SS Removal} = \frac{\text{SS influent} - \text{SS effluent}}{\text{SS influent}} \times 100$$

For example, if a lagoon has an influent SS of 300 mg/l and an effluent SS of 53 mg/l, then:

$$\%\ \text{SS Removal} \quad \frac{300 - 53}{300} \times 100 = 82\%$$

The pH of the influent should also be monitored and recorded daily. If the pH changes too drastically, it will produce an unfavorable environment for the biological mass and could upset the whole biological activity. The optimum influent pH range is 6.0 - 9.0, although lower pH's can be tolerated as long as the change isn't too sudden.

The pond(s) also needs to be monitored closely, since it is here that the treatment process is actually taking place. A daily DO check is very important. This determines if the pond is maintaining aerobic conditions. The DO should be taken at several locations to determine an average DO concentration.

The depth at which the DO concentration should be measured depends on the water depth of the lagoon, but generally 1/3 of the depth down is recommended. Care must be taken not to go down too far and penetrate into the anaerobic zone. A conscientious operator will watch the DO trends because they are indicative of biological activities and influent strengths. For example, if DO concentrations start dropping consistently, this may be the result of higher incoming BOD concentrations causing the micro-organisms to metabolize faster thus using more oxygen. If this overloading is occurring and a lagoon is already in a high load mode (parallel), then other options are available. Two of these are mechanical aeration or adding sodium nitrate (see Trouble-shooting - low DO). All efforts must be made to keep the lagoon aerated to prevent anaerobic conditions from developing.

Pond water temperature also needs to be measured; preferably at the same locations at which the DO's are measured. As previously mentioned in "Process Control," temperature has a direct effect on the biological activity. A decrease in temperature decreases treatment and longer detention times are needed to achieve adequate treatment. An increase in temperature accelerates biological activity which decreases DO levels.

pH should be measured about two times a week to insure that the pond is maintaining biological balance. If a pond is lacking in food, natural alkalinity or detention times, the pH will tend to be lower. The pond color can be used to visually determine any pH problems. A normal healthy facultative lagoon should have a nice green appearance. As pH drops the color will become a yellowish green caused by a type of algae which does well at lower pH's.

If a pond(s) looks abnormal in color, it is important to check the pH to discover if unfavorable pH conditions exist. pH will constantly be fluctuating due to normal microbial activity. Algae release more CO_2 than oxygen into the pond at night and lowers the pH somewhat. During the daytime the algae is most active producing larger quantities of oxygen which results in raised pH. pH will be at its highest in the late afternoon because of this phenomena. pH fluctuations can also be due to outside factors such as the industrial wastes and/or septic flows. If the pH of the pond becomes too acidic, it is advisable to let the cell rest for a few days to allow the pH to adjust back to the optimum level of 6.0 - 9.0.

Another test which is helpful in determining bacteria condition and age is the microscope scan. By observing the pond protozoa under a high-powered microscope, the operator can draw conclusions about the microbiological conditions. Protozoan life corresponds directly to the microbial conditions. A favorable pond condition will have a predominantly free-swimming population with stalks cillates and flagelletes, a few rotifers, and veryfew filaments. An example of an unfavorable condition is an uncontrolled filamentous growth. This may result from low DO's and/or pH's less than 6.5. Filamentous growths can be caused by other factors such as high carbohydrous wastes or a limiting nutrient condition. Very few or no protozoa could be indicative of a toxic condition while predominanting flagellates may be the result of a sludge recovering from a toxic condition and is usually accompanied by foam. The predominance of certain protozoa types is directly related to the sludge area. Since most lagoons have no control over their F/M ratio, the sludge is usually changing from the logarithmic phase into the endogenous respiration phase and back again. These constant flucuations will have a direct bearing on treatment and it is advisable to closely monitor the protozoa for this reason.

Respiration Rate, a test used to calculate the microbial oxygen uptake over a given time period, can also be a useful test to run on the pond contents. It is useful in describing the degree of existing biological activity. A respiration rate of 12 mg O_2/hr/gram of biological solids or greater is considered in the upper range and anything less than 12 mg O_2/hr/g is a low respiration rate. If microbial metabolism is high, a high respiration rate will be found and if for some reason that activity drops off the respiration rate will also drop.

Respiration Rates determinations in conjunction with microscope scans are useful tools for developing an insight into the microbiological growth activities in your lagoon.

Effluent testing is especially important because it is used to determine permit status and to determine the total treatment being obtained. As previously mentioned, it is used to calculate percent removal efficiencies of BOD and suspended solids. The removal of BOD and SS affects the oxygen demands placed on the receiving stream.

The following is a simplified formula used to determine the affect of effluent BOD on the receiving stream. It is derived by using the formula: Vol Conc = Vol_2 $Conc_2$.

Vol_1 = Lagoon effluent flow, MGD

$Conc_1$ = Lagoon effluent BOD, mg/l

Vol_2 = Total receiving stream flow (lagoon and stream flows), MGD

$Conc_2$ = amount of O_2 in mg/l removed from the stream in 5 days

For example -

Lagoon effluent = 3 MGD

Stream flow = 6 MGD

Effluent BOD = 25 mg/l

$$V_1C_1 = V_2C_2$$

$$3 \text{ MGD} \times 25 \text{ mg/l} = (3 + 6) \text{ MGD} \times Conc_2$$

$$75 = 9 \times Conc_2$$

$$75/9 = Conc_2$$

$$8.33 = Conc_2$$

If the stream DO content is only 8.0 parts DO, it can be seen that the BOD of 25 mg/l will adversely affect the oxygen content even though the reaeration factor must also be considered.

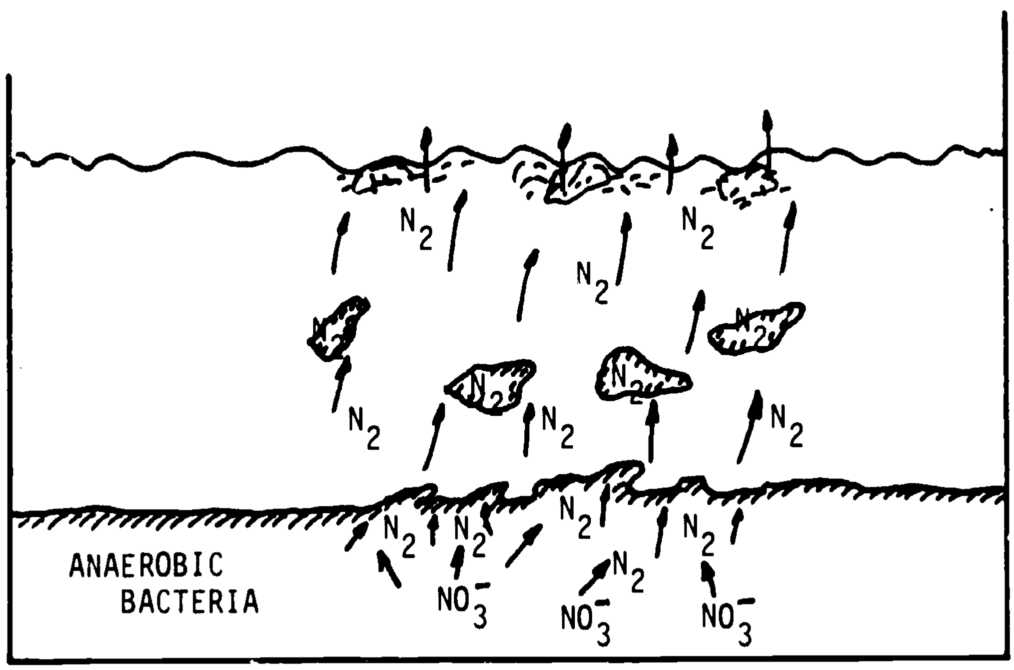
Effluent suspended solids will usually be higher in warmer weather due to increased algae growth. Chlorination of the effluent will help lower the algae suspended solids but will result in a higher BOD concentration which, in turn, places a higher oxygen demand on the receiving stream. Some lagoons have two different permit parameters; one for winter and one for summer which takes into consideration the fact that algae is a problem in summer. The frequency of testing the effluent for suspended solids and BOD is determined by the specified permit but increased monitoring can only result in better process control.

While discharging and chlorinating it is essential to test for chlorine residual daily. Effluent residuals vary as to allowable limits and it is best to check with NPDES permit. Over-chlorination can be toxic to fish and other aquatic animal and plant life. Too much chlorine can also kill algae. Although the dead algae will settle better, they will eventually cause an O_2 demand on the receiving stream due to the released organics. It is wise to carefully chlorinate the effluent and monitor closely to achieve a coliform disinfection without damaging too many algae. Chlorine dosage rates are determined by Cl_2 residual and this is another reason to check chlorine daily.

A major objective of wastewater treatment is the reduction of pathogenic microorganisms. The test used to determine this reduction is the fecal coliform test. Thus it follows that performing fecal coliform tests on the effluent is not only required by a good parameter on which to base effluent quality, it has been found that fecal coliform survival is inversely related to lagoon detention times. The longer the detention time, the better the coliform reduction. This is due to the evidence that the lagoon environment, with the long detention times and competing bacteria, is not well suited for the survival of pathogenic bacteria. Even so, it is almost always mandatory to chlorinate the effluent. Generally, counts of 200 fecal coliform per 100 ml on a monthly geometric mean is expected of most lagoons. This number varies and is specified by the NPDES permit.

It is often required to monitor nitrogen concentration on the effluent to determine the total nitrogen level being discharged into receiving streams. 20 mg/l of nitrogen can be harmful to fish life.

Nitrification, a process some lagoons experience, can be determined by running ammonia nitrogen and nitrate nitrogen tests. Nitrification, in itself, is not a problem except that it reduces DO levels and can lead to denitrification, which results in settled solids floating to the top. Nitrification is simply the conversion of the ammonia nitrogen into nitrates. The incoming organic nitrogen is acted upon by the microbes to form ammonia nitrogen, which is acted upon by a group of nitrifying bacteria called nitrosomas to form nitrates. Nitrites are unstable and undesirable but are fortunately acted upon immediately by nitrobacter which converts them into nitrates. Denitrification occurs when the settled nitrates are acted upon anaerobically releasing nitrogen gas. This naturally floats to the top in bubbles and carries with it the settled sludge.



Floating Sludge Caused By Denitrification

Figure 7

Phosphate, another essential nutrient for biological activities, should also be monitored. Phosphate is also found naturally in wastewaters and is contributed largely by cleaning agents. Too much phosphates will induce algae blooms and this causes problems with effluent suspended solids.

Although nothing can actually be done about too much phosphate, it is of value to understand that if there isn't enough phosphate it can be a limiting factor. This will inhibit bacteriological activities and result in poor treatment. Both nutrients, nitrogen and phosphate, although not usually a problem, need to be monitored occasionally, especially if treatment is poor and no other explanation can be found.

In order for sampling and testing to be effective process control tools, the information acquired needs to be recorded consistently and accurately. All recordkeeping should be precise and legible. Certain information needs to be recorded to fulfill your permit requirements, but all data needs to be kept and recorded for further analysis and process control. It is especially useful to have at hand all past data in order to follow trends and to learn from past conditions. Graphs are one way to closely monitor trends and to try to predict problems before they are a reality. If loading increases and the trend indicates it is a consistent increase, with effluent quality deteriorating, mode changes may be required.

Other information besides test results needs to be recorded daily also. These include weather (weather condition, temperatures, rainfall, wind direction), and pond depths (used to determine any suspected seepage, infiltration, plugged lines, etc.), for controlled discharge. Lagoon pond depth is very important to help determine if the pond(s) is low enough to allow adequate storage space during the holding season. Any unusual observations, problems, or safety hazards should also be recorded in a daily log book kept at the lagoon site.

LAGOON MAINTENANCE

There are some daily procedures that need to be practiced by the lagoon operator to help insure good, smooth lagoon operations. Every day certain observations should be made. These are not time consuming and can be done in just a few minutes but can be the source of many long hours of hard work if overlooked and left to cause eventual operational problems.

Visual Observations

A quick but thorough, visual observation is sometimes the fastest way for determining potential problems. A visual check of the pond color can tell the operator a lot about his/her lagoon. A normal pond will have a nice green appearance which indicates a high pH and DO. A dark pond may be the result of an anaerobic condition and will usually be accompanied by an unpleasant odor. A brown pond or turbid effluent may be the result of "pond turnover." This process generally occurs twice a year, once in spring and once in fall. Scum and/or floatables should be watched for and broken up or removed as necessary. Floating scum may be the result of grease or floating sludge mats which have floated to the top of the lagoon from the anaerobic zone below. Denitrification may be the cause of this and if it becomes too severe effluent quality may become worse.

Structure

The pond structure needs to be checked completely. This includes the inlet and effluent structures for normal flow conditions and for any cleaning requirements. All pre-treatment devices such as bar screens, flow meters, and grinders should be checked. Pump stations should be checked. Pump stations should be checked for operational problems, flow charts should be changed, and any debris removed. Also thoroughly check pumps for any unusual noises, oil levels, etc., and log all pump running times.

The dike itself needs a check for any leaking, erosion, or signs of burrowing animals. Also keep an eye out for any unwanted water or dike vegetation. These water weeds especially can be a problem because if they are left uncontrolled they can harbor insects, cause dike leakage, and prevent good even water flow. They also prevent sunlight penetration into water and lower DO concentrations. Be alert for any lagoon short circuiting such as "dead spots" in flow pattern. Flow should always be even and completely unobstructed.

Safety

Constantly be observant for any potential safety hazards. Any broken fences should be repaired immediately to prevent possible tragedies, and manhole covers should always be in place or barricaded. Often manholes at lagoons are located in a grassy area and are completely hidden until someone finds it the hard way!

Odor

Another important observation is for odor. A healthy lagoon should not have any unpleasant odors since odor indicates poor operating conditions. If obnoxious odors are present, corrective action needs to be taken immediately. (See troubleshooting under odor problems.

Recordkeeping

Daily recordkeeping as previously mentioned is an essential part of lagoon maintenance. The following are some parameters which should be recorded for your lagoon: Lagoon flows by meter and/or charts, weather conditions, cell conditions and depths, effluent conditions, pH and influent and pond water, DO's, temperatures, chlorine residual on effluent, chlorine dosage rate and lbs used, record BOD, SS, and Fecal Coli results when they are run, and any other tests results that may have been performed.

Preventative Maintenance

While performing your daily lagoon maintenance, it is extremely important to do preventative maintenance on all equipment. All pumps should be checked for several conditions which, if left unattended, could become a future serious problem. Excessive water dripping should be noted and corrected, either by replacing the packing or installing a new mechanical seal. Check pumps for any abnormal vibrations or noises which could be caused by a plugged condition. Oil levels have to be monitored daily and filled if necessary. Check all motors for overheating since this may be the result of an electrical short, a worn pump, or bad motor bearings.

Grinding devices can be another source of operational problems if not checked routinely. They should be working smoothly and not plugged with rags or other debris. Check the cutter blades regularly and lubricate as needed. Flow meters, the basis for determining lagoon loading, are very critical for operational control. Therefore these need to be checked and cleaned (floats on float type) and field calibrated periodically. If uncertainty exists as to calibration checks on your particular meter, contact company for an O and M manual or request their assistance. Remove any condensation inside sight glass to make meter reading easier, faster, and more accurate. If condensation becomes a consistent problem, a new "O" ring may be needed.

Daily checks on the chlorinator is also advised. Feed rates, remaining lbs of chlorine, and pressure gauges need to be checked and recorded. Change chlorine tank or cylinder as needed using two people and extreme caution. Check for any leaks, especially around the yoke connections, by using ammonia-water vapors. Always keep chlorinator and tanks or cylinders as dry as possible and at about $70^{O}F$.

LAGOON TROUBLESHOOTING

Facultative lagoons may, on occasion, experience some common operational problems. These usually result in decreased lagoon efficiency and thus effluent quality begins to deteriorate. Some of these problems can also cause potential health hazards. The following troubleshooting keys cover some of the more common problem areas and are intended to be used as general guidelines to aid in correction and prevention of these items.

Troubleshooting is a two-fold adventure and performing only one of these will not result in total elimination of the problem or problems. The first step in troubleshooting is to "cure" or "correct" the immediate problem to prevent further deterioration of lagoon effluent quality. After this has been accomplished and lagoon is "up and running" again, it is important to find the cause of that problem and to try and correct it in order to prevent similar conditions in the future, and to prevent the problem from becoming worse.

HIGH LOADING PROBLEMS

CAUSES

1. Lagoon under designed.
2. Hydraulic overloading--possibly due to infiltration.
3. Industrial wastes.
4. Wrong operational mode.
5. Short circuiting.
6. Adverse weather conditions.
   a. heavy rainfall.
   b. storm drains adding flow.

SOLUTIONS

1. Consider adding another primary cell.
2. Change to parallel mode.
3. Supplemental aeration
   a. see low DO section
4. If only one cell affected bypass it and let it rest.
5. Recirculation - supplies extra DO and dilutes organic wastes.
6. Correct any short circuiting.

INDICATORS

1. High effluent BOD
2. Low pH's
   a. unbalanced population of bacteria and algea which drives pH down.
3. Low DO
   a. algae is unable to supply the required DO demand--results from increased micro metabolism.

DECREASING TREND IN pH

CAUSES

1. Drop in DO as green algae die off.
   a. caused by overloading, adverse weather, or environmental conditions, presense of daphnia crustation feeding on algae.

SOLUTIONS

1. Bypass cell to let it rest.
2. Change to parallel mode.
3. Apply recirculation of effluent.
4. Correct any shortcircuiting.
5. If due to low DO use supplementary aeration (see low DO).
6. Toxic conditions killing algae--correct at source.

EFFLUENT HIGH IN S.S.

CAUSES

1. Algae blooms
   a. see algae removal
2. Stratification
3. Inadequate treatment
   a. short DT
   b. filamenlous growths
4. Sudden temperature increases
5. Cold temperatures (see temperature process control)

SOLUTIONS

1. Remove algae
2. Wait for solids to resettle after stratification.
3. Increase DT in cold temperatures.
4. Change mode to series to increase treatment DT.

EFFLUENT HIGH IN BOD

CAUSES

1. Overloading
   a. see high loading problems
2. Short detention times
   a. hydraulically overloaded
   b. wrong operational mode
3. Toxic compounds
   a. biological activity stops, not adequate treatment.
   b. will recover if toxic condition is corrected.
4. Algae
   a. chlorinated effluent high in algae causes release of substrates which add BOD.

SOLUTIONS

1. Reduce organic loading
   a. change modes to parallel.
2. Reduce hydraulic loading
   a. eliminate infiltration
3. Recirculate effluent back to primary cells to finish treatment of organic wastes.
4. Remove algae prior to chlorination.
   a. Rock filters
   b. subservice withdrawals
   c. baffles and wiers

LOW DO

CAUSES

1. High organic loading.
2. Weeds preventing sunlight penetration.
3. Short detention time.
4. Ice cover.
5. May be indicated by unpleasant odors and dark pond color.

SOLUTIONS

1. Reduced loading change to parallel mode.
2. Remove weeds or any other vegetation stopping sunlight and wave action.
3. Add supplemental DO
   a. mechanical aerators
   b. diffused oxygen
   c. motor boat trips daily
   d. recirculation of effluent
   e. pre-aeration
   f. sodium nitrate (see odor control)

ALGAE REMOVAL

CAUSES

1. Result in high effluent suspended solids.
2. Caused by favorable conditions
   a. warm weather
   b. sunlight
   c. excess phosphorous

SOLUTIONS

1. Subsurface withdrawals.
2. Baffles and wiers.
3. Chlorination prior to discharge
   a. caused high BOD results
4. Use of multiple ponds.
5. Series mode favors less algae growths.
6. Phase isolation
   a. using multiple cells fill one secondary to capacity. Chlorinate and let settle while filling second secondary. While chlorinating this cell draw off first cell.
7. Rock filter - effluent ran through rock medium.

INSECTS

CAUSES

1. Uncontrolled aquatic growth.
2. Surface scum.

SOLUTIONS

1. Flood aquatic growth.
2. Spray carefully with herbicides or insecticides.
3. Stock pond with gumbusia (mosquito fish)
4. Practice larva control
   a. check with state regulatory officials.
   b. check soil samples around lagoon every 2 weeks in spring.
   c. apply larvacides - use on a quiet day and use around edges of pond(s).
   d. effective larvacides
      1. BHC dust (3 gamma isomer)
      2. thin layer of diesel oil
      3. 2% malathion emulsion
      4. dursban
      5. naled
      6. fenthion
      7. abate

ODOR PROBLEMS

CAUSES

1. Overloading
2. Low sunlight penetration (causing low DO)
3. "Spring Turnover" (stratification)
4. Short circuiting.
5. Influent high in industrial or septic wastes.

SOLUTIONS

1. Change mode to parallel to reduce loading
2. Increase DO
   a. use of sodium nitrate
      1. use 200 lbs SO_4/MG
      2. use 100 lbs SO_4/acre for 1 day then reduce to 50 lbs SO_4/acre until odor subsides.
      3. Apply at influent wet well or in wake of motorboat. SO_4 is very soluble.
3. Aerate by mechanical means.
   a. floating aerators
   b. diffused aeration
   c. pre-eration of influent
   d. motorboat trips
4. Recirculate pond effluent.
   a. recycle effluent back to beginning of secondary pond or primary where needed.
5. Eliminate high strength influent flows.
   a. contact industry or septic contributor if known.

DIKE VEGETATION

CAUSES	SOLUTIONS
1. Provides nesting place for burrowing animals.	1. Seed dike with grasses that will "out compete" other vegetation. a. mixture of fescue and blue grass
2. Cause weakening of dike.	2. Spray with environmentally safe spray. a. Check with regulatory officials
3. Reduces wind action on lagoon surface.	3. Keep mowed or burn.
4. Blocks sunlight.	4. Use small animals such as sheep or goats.

BURROWING ANIMALS

CAUSES	SOLUTIONS	TYPE
1. Tunnels will weaken dike.	1. Remove weed growths to discourage.	1. Muskrat
2. Cause seepage.	2. Traps and/or firearms a. check with local game commision officer.	2. Moles

PROBLEM WATER WEEDS

1. Provide food for burrowing animals.
2. Prevents sunlight penetration and therefore can lower DO levels.
3. Provides harborage for mosquitos and other insects.
4. Obstructs normal flow patterns and causes shortcircuiting.
5. Stops wave action necessary for surface aeration.

1. Pull weeds by hand when they are young.
2. Spray with environmentally safe commercial herbicide.
   a. Dow Dalapon for cattails
   b. Dow Silvex for willows and emergent weeds
   c. Ortho-Endo-thal for suspended weeds
   d. copper sulfate for filamentous algae
   e. simazine for weeds
3. Lower water level and mow or burn weeds inside dike.
4. Increase water level to above weeds to prevent growth.
5. Install rip-rap after removing weeds to prevent future problems.

1. Cattails
   a. Pull while young, before they colonize.
   b. lower water level and then cut when flowering heads are 1/2 to 2/3 formed in early summer.
   c. use of sheep or goats to keep in control - lower water level.
   d. use commercial spray
2. Duckweed
   a. Remove with rakes, boards, etc.
   b. use commercial spray
   c. use a few tame mascovy ducks per acre to control.

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References

"A Course on Operational Considerations in Wastewater Treatment Plant Design," U.S. EPA and Kirkwood Community College, Cedar Rapids, IA, 1978.

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"Solids Treatment & Disposal," Course #166, U.S. EPA and Linn-Benton Community College, Albany, OR, 1980.

"Wastewater Engineering Treatment Disposal," Metcalf & Eddy, Inc., McGraw-Hill, New York, 1972.

FACULTATIVE LAGOONS

Worksheet

1. The three vertical zones in a facultative lagoon are:

   ____

   ____

   ____

2. Oxygen is supplied to a facultative lagoon by __________ and ________________.

3. In the symbiotic relationship between algae and bacteria algae produce ______________ which is used by the aerobic bacteria. The bacteria produce ________________ as a by-product which is used by the algae.

4. The only control parameter for a single cell lagoon is ______________.

5. A parallel flow pattern is used when ______________________________ ____.

6. A series flow pattern is used when ______________________________ ____.

7. Cold temperatuares combined with short days will __________ microbial and algae metabolism.

8. The phenomenon of warm bottom water rising to the surface in the spring when the ice cover melts is called __________________________.

9. When carbon dioxide accumulates the pH will __________________.

10. A __________________ color usually indicates basic pH levels.

11. List the tests that should be performed on the pond influent.

12. List the tests that should be done on the pond effluent.

13. List the tests that should be done on the pond itself.

14. Calculate the organic loading rate for a lagoon with the following characteristics:

Length	=	500 ft.
Width	=	500 ft.
Influent BOD	=	130 mg/l
Flow	=	175,000 gal/day

15. Calculate seepage rate for the following conditions:

Influent	=	60,000,000 gal/yr
Effluent	=	57,500,000 gal/yr
Precipitation	=	26 inches/yr
Evaporation	=	16 inches/yr
Surface Area	=	250,000 sq. ft.